Space Technology Research Grants

Mass Measurements of an Electrospray Beam from a Single Emitter Ionic Liquid Ferrofluid Electrospray Source

Completed Technology Project (2013 - 2017)

Project Introduction

The research that will be conducted in its broadest sense is experimentally measuring the electric field that is used in micro-scale propulsion devices. The key objectives are engrained in both proof-of-concept, and development of a technique to make this measurement around a dynamic conical feature called a Taylor cone. Literature shows that the technique, called electron holography, has been successfully used to measure the electric field of similar sized solid features. There is also literature that proves imaging of Taylor cones is possible in the transmission electron microscope used for electron holography. This research would therefore bridge this gap in literature and provide experimental data that can be used to solve problems seen in recent electric propulsion modeling and experiments. The hypothesis that will be tested in this experiment is the following, if an operating ionic liquid Taylor cone subjected to changes in the local electric field, then the measured emission current will follow a proportional trend with respect to an increase in electric field. In order to test this hypothesis, the following questions must be answered: 1. How does the aspect ratio of these sharp tips affect the formation of the Taylor cone? 2. Is it possible to measure the spatial electric field in the near field of an operating Taylor cone? 3. How do variations in the local electric field affect the operation of an ionic liquid electrospray thruster? To answer the first question three experiments will be conducted using the two in situ visualization techniques previously described. The experiments will use a Hitachi S4700 field-emission scanning electron microscope (FE-SEM), a FEI Titan 80-300 environmental transmission electron microscope (E-TEM) with an integrated Mollenstedt biprism, and a JEOL JEM-4000FX transmission electron microscope (TEM), respectively. I have successfully completed the FE-SEM experiments using an uncoated sharp tungsten tip as the cathode. The first TEM experiment will use the electron holography technique to image the spatial electric field in the region around an uncoated tungsten tip of varying tip radii. These TEM results will then be used as a means of comparison for the SEM micrographs. From the results of these two experiments will help in selecting the proper range of tip radii for use in the coated tip experiments. The second TEM experiment will implement an ionic-liquid-coated tungsten tip to produce and image a stable Taylor cone. Multiple tips with varying tip radii will be testing until a Taylor cone formation is demonstrated. As such, this TEM experiment will focus on imaging an ionic liquid Taylor cone forming on a tungsten tip and will not use any electric field measurement techniques. To answer the second question the FEI Titan 80-300 E-TEM will be used to run experiments on operating ionic liquid Taylor cones. The electron holography technique will be used again, this time to image the spatial electric field surrounding stable Taylor cones. Once visualization of the electric field around operation Taylor cones is demonstrated, images will be taken at different applied voltages to measure the determine how a change in the electric field affects the operation of a Taylor cone. To answer the third question, emission current can be measured concurrently with image capture to observe the effect the local electric field has on emission current. This research would be a

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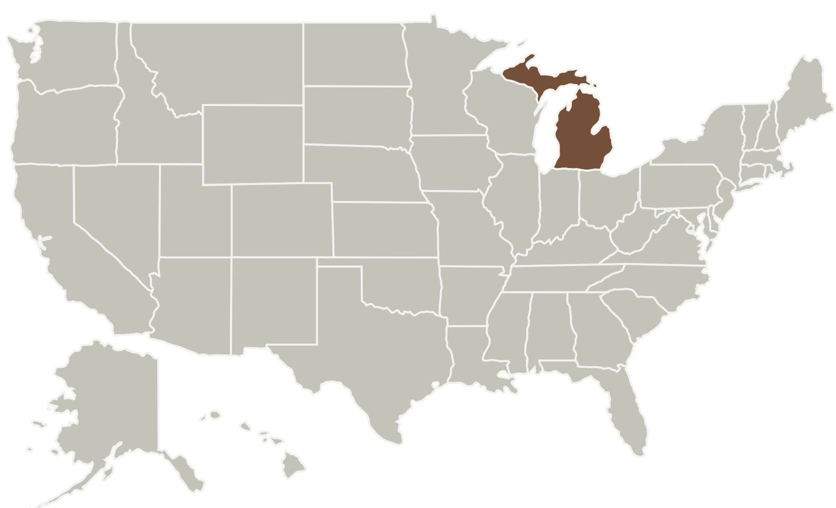
significant step in challenges currently seen in the micropropulsion arena. Specifically, within NASAs In-Space Propulsion TABS, challenges in MEMS electrospray technology that could be solved would be the ability to design power efficient electrospray thrusters. Understanding the experimentally measured relationships between the local electric field and Taylor cone operation, or local electric field and the emission current could also lead to solutions in distribution of propellant on emitter tips.

Anticipated Benefits

This research would be a significant step in challenges currently seen in the micropropulsion arena. Specifically, within NASAs In-Space Propulsion TABS, challenges in MEMS electrospray technology that could be solved would be the ability to design power efficient electrospray thrusters. Understanding the experimentally measured relationships between the local electric field and Taylor cone operation, or local electric field and the emission current could also lead to solutions in distribution of propellant on emitter tips.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Michigan Technological University(MTU)	Lead Organization	Academia	Houghton, Michigan

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Michigan Technological University (MTU)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Lyon King

Co-Investigator:

Kurt Terhune

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Primary U.S. Work Locations

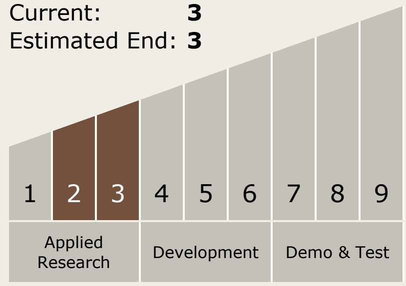
Michigan

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX01 Propulsion Systems
  - └ TX01.2 Electric Space Propulsion
    - └ TX01.2.2 Electrostatic

Target Destinations

Earth, Others Inside the Solar System, Foundational Knowledge